Title: Multi-Model Ensemble Forecast of MJO

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John Gottschalck, Arun Kumar and Jae-Kyung E. Schemm at Climate Prediction Center /NCEP/NWS/NOAA.
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Requested budget Year1: $172,171; Year2: $167,948; Year3: $172,499

Abstract

The Madden-Julian Oscillation (MJO) is the most prominent form of intraseasonal variability in the tropics and a primary source of predictability for sub-seasonal variations, including those in the subtropics and extra-tropics. This predictability extends to many aspects of low-frequency weather modulation, including high impact events such as hurricanes, as well as tropical-extratropical interactions that can lead to extreme precipitation events for example along the US west coast. Dynamical models have improved greatly in the past decade and a few models have produced rather credible simulations of the MJO, with evidence of useful prediction skill of the principal characteristics of the MJO out to a lead-time comparable to empirical-statistical schemes. Despite significant societal and environmental demands for accurate prediction of MJO and notable improvements in our ability to simulate the MJO, operational prediction of MJO and intraseasonal variability (ISV) is still in its infancy and its achievement seen as a great challenge faced by operational weather forecast centers.

The objective of the proposed research is to improve MJO prediction in CFS model and to develop a Multi-Model Ensemble (MME) methodology, based on coupled atmosphere and ocean models (CGCMs), for the operational prediction of the MJO and associated N. American impacts during boreal winter. In order to fulfill this objective, our proposed work consists of the following development tasks: I) Construct a well-designed and coordinated hindcast experiment using seven coupled global models. II) Use the hindcast experiment to assess the predictability and prediction skill of the MJO and related N. American impacts during boreal winter. III) Examine the prediction skill sensitivity to aspects of initialization as well as structural and parameterization differences within the multi-model hindcast. IV) Use the hindcast experiment to develop an MME technique suitable for MJO prediction and assess improvements in MJO

2. ABSTRACT

Title: Collaborative Research: Enhancing operational drought monitoring and prediction products through synthesis of N-LDAS and CPPA research results

PIs and Institutions: Eric F Wood (efwood@princeton.edu), Princeton University
Dennis P. Lettenmaier (dennisl@u.washington,edu), Univ. of Washington

Total proposed cost: $549,896; (Princeton: $297,700; UW: $252,196)

Budget Period: May 1, 2010 – April 30, 2013 (3 years)

Drought has had tremendous societal and economic impacts on the United States. In April 2003 the Western Governors in partnership with NOAA initiated planning for a *National Integrated Drought Information System (NIDIS*), which was implemented by Congress with NOAA as the lead agency. The NIDIS concept is that drought management should be risk-based, and aimed at better quantitative monitoring, early warning and prediction. The NOAA Climate Test Bed (CTB) was established "*To accelerate the transition of scientific advances from the climate research community to improved NOAA climate forecast products and services"*. Studies over the last two decades have demonstrated the feasibility of making useful seasonal climate predictions, with the expectation that associated outlooks and forecasts can contribute to seasonal hydrologic and drought prediction capabilities. Developing a seasonal hydrological and drought forecasting capability has been the goal of the NOAA Climate Program Office's (CPO) Climate Prediction Program for the Americas (CPPA) through its research support to external investigators, including the PIs, and CPPA's Core Project funding to NCEP's Environmental Modeling Center (EMC) and the NWS Office of Hydrologic Development (OHD) in support of the North American Land Data Assimilation System (NLDAS). We propose herein to transition, in cooperation with EMC and the NOAA Climate Prediction Center (CPC), advances in seasonal hydrological and drought forecasting made at Princeton University and the University of Washington to the CTB. This constitutes a critical next step in enhancing CPC's operational drought prediction capabilities.

This proposal responds to priority area 3 of the FY 2010 CTB Information Sheet: *Enhancing Operational Drought Forecast Products and Applications*. Operationally, CPC provides leadership in drought assessments within NOAA by providing drought outlooks and monitoring through its contributions to the National Drought Monitor (DM) and its Seasonal Drought Outlook (DO). Current procedures underlying the DM and DO rely on a suite of information that includes primarily qualitative evaluations of current hydrologic and agricultural conditions, combined with (in the case of the DO) seasonal climate forecasts. CPC would like to transition to *objective* drought monitoring and prediction approaches. EMC, through funding from CPPA. has executed pilot demonstrations of a multi-model hydrological drought monitoring system based in substantial part on approaches developed by the PIs and implemented in experimental systems at the PIs' institutions, e.g. the University of Washington National Surface Water Monitor. Both PIs have participated extensively in adaptation of CPPA-funded research to these EMC pilot demonstrations.

The proposed project will transition the multi-model seasonal hydrologic and drought monitoring and prediction capabilities developed by the PIs and EMC to the CTB. These existing pilot systems use procedures developed by the PIs that bias correct and downscale seasonal forecasts from CFS dynamical forecasts and CPC official outlook products, as well as simpler methods that resample from climatologies. NLDAS products are used to provide initial conditions for the hydrological and drought predictions as well as real-time monitoring of drought. Overall, these activities have demonstrated that the systems are now sufficiently mature to merit a more rigorous, robust and continuous execution and evaluation via the Climate Test Bed (CTB). We will work closely with our EMC and CPC collaborators to implement a drought monitoring and prediction system in the CTB. Testing and evaluation of the system will utilize the NIDIS Southeast testbed, with special attention to the Savannah and Apalachicola-Chattahoochee-Flint River basins, the latter of which is the water supply source for Atlanta, which has been particularly prone to drought in recent years.

NOAA Climate Test Bed

Improved Extended-Range Prediction through a Bayesian Approach: Exploiting the Enhanced Predictability Offered by the Madden-Julian Oscillation

Principal Investigator: *Shang-Ping Xie (International Pacific Research Center)*

Co-Principal Investigators: *Nathaniel Johnson (International Pacific Research Center), Steven Feldstein (Pennsylvania State University),*

Collaborators: *Michelle L'Heureux, Dan Collins, and Jon Gottschalck (NOAA/NCEP/CPC)*

Total Proposal Cost: $331,927 (UH Contribution: $234,962, PSU Contribution: $96,965)
Budget Period: May 1, 2010 to April 30, 2013

<u>Abstract</u>

We propose to implement a Bayesian framework in a Multi-Model Ensemble (MME) approach for the purpose of enhancing current NCEP/CPC products, such as the operational extended-range predictions (6-10-day, 8-14-day, and Weeks 3-4) over North America. In particular, we plan to exploit the potential enhanced predictability in the mid- to high-latitudes associated with the Madden-Julian Oscillation (MJO). The proposed Bayesian framework provides a means of building a bridge between the statistical relationships uncovered in previous studies and recent advances in dynamical forecast models that are heavily used in operational CPC forecasts. The primary purpose of our proposed project is twofold: (1) to extend our knowledge on the geographical areas and lead times for which the MJO may offer enhanced predictability, and (2) to transition that knowledge to enhance operational NCEP/CPC forecast products focusing on circulation changes related to MJO-variability. We expect that these enhanced climate forecast products will directly benefit a wide range of user communities.

Proposal Title: Seasonal Prediction for Ecosystems and Carbon Cycle Using NCEP/CFS and a Dynamic Vegetation Model

Institution: University of Maryland, College Park
Principal Investigator: Ning Zeng**; Co-PI:** Eugenia Kalnay
NOAA Collaborator: Arun Kumar (NCEP/CPC)

Abstract

In recent years, many advances have been made in the science and practice of seasonal climate predictions. For example, seasonal climate predictions have attained operational status and have come to rely increasingly more on dynamical prediction models. Such advances notwithstanding, application of seasonal climate outlooks to applications of societal importance has been slow to materialize. The aim of this proposal is to develop one such application, i.e., *a capability to forecast terrestrial ecosystem productivity and carbon sources and sinks on seasonal-interannual time-scale*. The modeling system is global, but the focus of validation and application will be for North America.

The development of an outlook capability for the ecosystem will rely on several components that have evolved following independent pathways and have reached a state of maturity in their respective domains of interest. The key effort of this proposal will be bringing together these modeling and prediction component systems.

The modeling components of the proposed predictive capability include:
1. A dynamic Vegetation-Global-Atmosphere-Soil (VEGAS) model with full terrestrial carbon cycle
2. Operational climate forecasts at the Climate Prediction Center and dynamical seasonal forecasts based on the Climate Forecast System (CFS) (both at NCEP)

Specific tasks under the proposal will include (and will build upon a prototype carbon cycle prediction already in place):
- Developing a procedure to specify vegetation and soil initial conditions derived from some form of data assimilation system
- Developing procedures to forecast ecosystem and carbon variables using ensemble climate prediction information from CFS
- Validation of prediction system based on hindcast skill by comparing model predictions against a suite of observed variables such as satellite vegetation index, CO_2 flux measurements, and assimilated carbon fluxes
- Comparison of the CFS based skill with other baseline estimates of skill for predicting eco-carbon variables, e.g., prediction based on operational CPC forecasts
- Testing the prediction system in a real-time operational setting, getting feedbacks from a wider community, improving the system.

Deliverable of this project will be a seasonal forecasting system for terrestrial ecosystem productivity and carbon fluxes that later will be transitioned to operations using the Climate Test-Bed (CTB) infrastructure.

Incorporating Scale and Predictability Information in Multi-model Ensemble Climate Predictions

Investigators:

- Timothy DelSole (PI), George Mason University
- Michael Tippett, International Research Institute
- Huug van den Dool, Climate Prediction Center, NCEP

Total Proposed Cost: \$461,330
Budget Period: January 1, 2010 - December 31, 2012

We propose to develop a new multi-model ensemble prediction system based on a theoretical framework that constrains the spatial structure of the multi-model weights and filters out unpredictable components from the analysis. Several previously proposed multi-model methods emerge naturally from this framework, including ordinary least squares, multi-model averaging, covariance localization, and ridge regression. Importantly, however, the framework provides a new way to impose realistic spatial coherence in the multi-model weights without invoking ad hoc smoothing after the fact. As a by-product, the proposed research will produce a set of maximally predictable components– i.e., a complete, uncorrelated set of components that maximize predictability over the full multi-model ensemble. These predictable components provide the basis for filtering out unpredictable components from the forecasts and are of theoretical and practical interest in their own right. Anticipated results from this research include:

- A state-of-the-art multi-model forecast system that constrains the spatial structure of the model weights and accounts for predictable structures in the respective models.
- A clear and rigorous assessment of whether the skill of the multi-model forecast system is substantially superior to simple pooling methods.
- A complete, uncorrelated set of maximally predictable components for each variable ordered such that the first maximizes predictability, the second maximizes predictability subject to being uncorrelated with the first, and so on.
- A comprehensive assessment of the skill of different state-of-the-art forecast models, especially how the CFS skill compares to other models.

CPT for Improving the Representation of the Stratocumulus to Cumulus Transition in Climate Models

Lead Principal Investigator:
Dr. Christopher Bretherton, Professor
Department of Atmospheric Sciences, University of Washington, Seattle, WA USA

Dr. Carlos Roberto. Mechoso, Professor
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Dr. Sungsu Park
National Center for Atmospheric Research, Boulder, CO USA

Desired Grant Period: July 1, 2010 – June 30, 2013

Abstract

In 2007 the **IPCC** reiterated that *clouds remain the largest source of uncertainty* in climate projections. In this context, boundary layer clouds, and in particular the transition from stratocumulus to cumulus, play a key role in the cloud-climate feedback. These clouds are also important to the surface energy balance and the Sea Surface Temperature (SST) distribution and are key elements in biases in seasonal coupled model forecasts and simulated mean climate.

Current climate and weather models are still far from realistically representing clouds. Improving the representation of clouds in climate models is fundamental to improving confidence in both seasonal and long-term climate projections. Both the NCAR and NCEP models have been recently upgrading their cloud, boundary layer, and shallow cumulus convection parameterizations. Several recent studies (e.g. the GCSS Pacific Cross Section Intercomparison and the Pre-VOCALS model intercomparison) have shown that these models are nevertheless not adequately simulating subtropical stratocumulus and the transition to cumulus.

The objectives of this proposal are to improve the representation of the stratocumulus-to-cumulus transition in the NCAR and NCEP climate models by (i) improving the interactions between existing model parameterizations by combining careful single-column modeling with sensitivity studies using weather-forecast mode and coupled-ocean global simulations, (ii) implementing probability density function (PDF) cloud parameterizations for boundary layer clouds, (iii) optimizing the combination between eddy-diffusivity and mass-flux vertical mixing parameterizations; (iv) creating model diagnostic tools necessary to evaluate the representation of the stratocumulus to cumulus transition.